STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF FACILITIES CONSTRUCTION
OFFICE OF TRANSPORTATION LABORATORY

EXPERIMENTAL OVERLAYS UTILIZING MAGNESIUM PHOSPHATE, METHYL METHACRYLATE AND POLYESTER-STYRENE CONCRETES

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This project was performed in cooperation with the U.S. Department of Transportation, Federal Highway Administration, under the research project entitled, "Experimental Concrete Overlays."

16. ABSTRACT

Details are listed for pavement overlays less than one inch thick. Three different materials were used: magnesium phosphate, methyl methacrylate, and polyester-styrene concretes. Each section is 24 feet wide and from approximately 1100 feet to 1300 feet in length. Construction problems were encountered and are discussed. The polyester-styrene concrete overlay performed best with no delamination. The magnesium phosphate concrete and the methyl methacrylate concrete overlays failed due to debonding. Surface preparation for thin bonded overlays was found to be a significant factor.

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NOTICE

CONVERSION FACTORS

English to Metric System (SI) of Measurement

Quality	English unit	Multiply by	To get metric equivalent
Length	inches (in)or(")	25.40 .02540	millimetres (mm) metres (m)
	feet (ft)or(')	.3048	metres (m)
	miles (mi)	1.609	kilometres (km)
Area	square inches (in^2) square feet (ft^2) acres	6.432×10^{-4} .09290 .4047	square metres (m^2) square metres (m^2) hectares (ha)
Volume	gallons (gal) cubic feet (ft^3) cubic years (yd^3)	3.785 .02832 .7646	litre (1) cubic metres (m^3) cubic metres (m^3)
Volume/Time (Flow)	cubic feet per second (ft^3/s	28.317	litres per second 1/s)
	gallons per minute (gal/min)	.06309	litres per second (1/s)
Mass	pounds (lb)	.4536	kilograms (kg)
Velocity	miles per hour (mph) feet per second (fps)	.4470 .3048	metres per second (m/s) metres per second (m/s)
Acceleration	feet per second squared (ft/s^2)	.3048	metres per second squared (m/s^2)
	acceleration due to force of gravity (G) (ft/s^2)	9.807	metres per second squared (m/s^2)
Density	(lb/ft^3)	16.02	kilograms per cubic metre (kg/m^3)
Force	pounds (lbs) (1000 lbs) kips	4.448 4448	newtons (N) newtons (N)
Thermal Energy	British termal unit (BTU)	1055	joules (J)
Mechanical Energy	foot-pounds (ft-lb) foot-kips (ft-k)	1.356 1356	joules (J) joules (J)
Bending Moment or Torque	inch-pounds (in-lbs) foot-pounds (ft-lbs)	.1130 1.356	newton-metres (Nm) newton-metres (Nm)
Pressure	pounds per square inch (psi)	6895	pascals (Pa)
	pounds per square foot (psf)	47.88	pascals (Pa)
Stress Intensity	kips per square inch square root inch ($ksi\sqrt{in}$)	1.0988	mega pascals$\sqrt{metre}$ ($MPa\sqrt{m}$)
	pounds per square inch square root inch ($psi\sqrt{in}$)	1.0988	kilo pascals$\sqrt{metre}$ ($KPa\sqrt{m}$)
Plane Angle	degrees (°)	0.0175	radians (rad)
Temperature	degrees fahrenheit (F)	$\frac{+F - 32}{1.8} = +C$	degrees celsius (°C)

ACKNOWLEDGEMENTS

The contributions of District 3 Offices of Design and Maintenance are gratefully acknowledged. Special thanks go to Bill Neal, since retired, for his knowledgeable contributions and guidance to this study.

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Henry Jerzak
Harvey Sterner
Dave Wong

Report typing:

Marti Garcia-Corralejo

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INTRODUCTION

This report is the third of a series covering experimental overlays of Portland Cement Concrete (PCC) pavement in the mountain area of I-80 in Northern California. The major problem necessitating the overlays is not structural adequacy, but loss of surface mortar and aggregate particles due to tire chain wear and freeze-thaw action. To restore the pavement surface and improve riding quality, three strategies were selected for evaluation:

1. Thin bonded PCC overlay with a nominal 3-inch thickness using high quality concrete. A report on this project was published previously (1).

2. An AC overlay employing new strategies and design concepts. A report on this project was also published previously (2).

3. Very thin "exotic" concrete overlays of 3/8-inch minimum thickness using materials that are relatively new to highway construction. This strategy is the subject of this report.

In 1979, short trial sections of very thin overlays were placed (3). Based on the results of those test sections, the following three materials were selected for further evaluation:

1. magnesium phosphate concrete
2. methyl methacrylate (MMA) concrete
3. polyester-styrene concrete

SUMMARY AND CONCLUSIONS

Magnesium phosphate concrete does not appear to be flexible enough for use as a thin bonded overlay. The magnesium phosphate concrete overlay is a failure due to delamination and spalling. However, magnesium phosphate concrete may work well if adequate surface preparation is done and no reflective cracking stresses are present.

The methyl methacrylate concrete (MMA) has delaminated and spalled to a lesser degree than the magnesium phosphate concrete. Its resistance to abrasion due to tire chain wear has been satisfactory. Thus, the MMA concrete may have merit as an overlay material if the bond to PCC can be improved. The MMA polymer concrete was the most expensive material tested.

The polyester-styrene concrete has performed fairly well with no loss of bond or spalling. The overlay has experienced considerable wear and occasional loss of coarse aggregate. However, it was demonstrated that the polyester-styrene concrete is a feasible and satisfactory material for thin bonded overlays even though improvement in construction techniques and the concrete formulation is required. Poor construction techniques resulted in the significant initial wear. The polyester-styrene concrete provided the best performance for the lowest cost of the three materials tested.

None of the crack repair strategies tested prevented reflective cracking. Repairing cracks by the strategies tested before the placement of a thin bonded overlay, is not considered cost effective.

Sandblasting of the pavement surface was not adequate to ensure good bonding of the magnesium phosphate and MMA overlays. The use of steel shot blasting equipment for surface preparation is recommended for any future overlay projects utilizing these materials.

IMPLEMENTATION

A polyester concrete overlay was placed adjacent to the test section described in this report in September 1984 under contract 03-299204. Two types of polyester resins were placed. Along with the resin (Type II) described in this report, a resin (Type IV) with less flexibility, higher compressive strength, and higher flexural strength was also placed. Improved prime coat resins were used to help ensure bond. The construction equipment used was similar to the equipment described in this report, but knowledge gained in this study helped improve construction techniques. New resins and better consolidation of the polyester concrete resulted in improved overlay performance.

A nine lane mile polyester-styrene concrete overlay contract, 03-255334, was awarded in April 1985. This contract included both Type II and IV polyester resins and specified a mobile, screw-auger type, continuous mixer. The finishing equipment used to place the polyester concrete was a self-propelled slip form paving machine (Gomaco C-2500). This contract is on Interstate 80 in Placer County, post miles 49.2 to 52.8.

Thus, the study described herein has been instrumental in the development of thin polymer overlays. Information gained in this study has been and will continue to be applied to many highway and bridge deck polymer overlays.

OVERLAY PROJECT DESIGN DETAILS

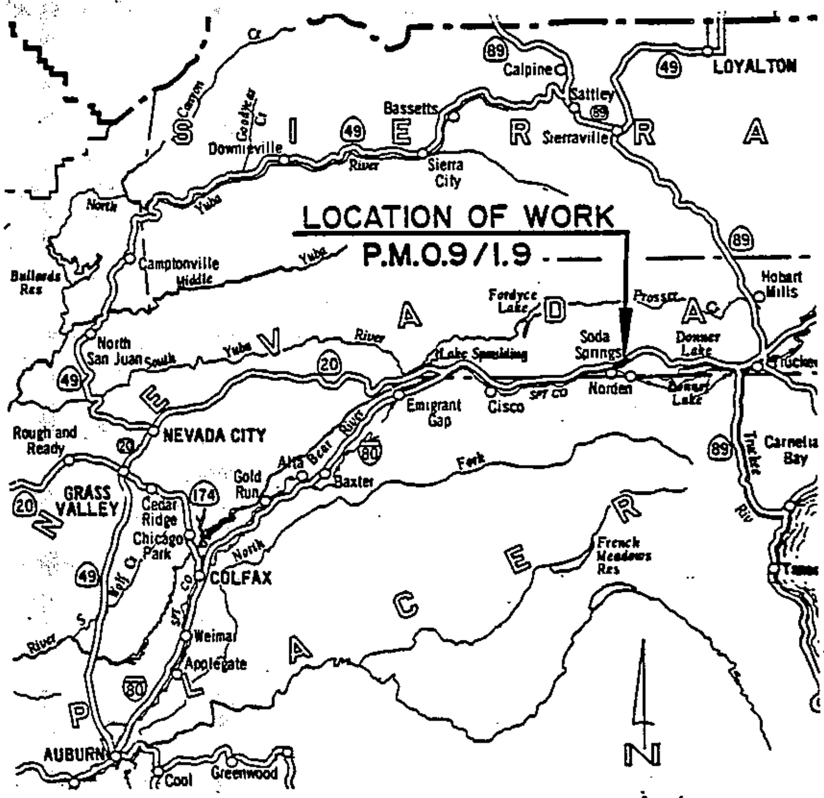
Site Selection

The test site was located on eastbound Interstate 80 in Nevada County between post miles 0.9 and 1.9. The location (Figure 1) is at approximately 6500 foot elevation on a +5% grade with varying superelevations up to 8%. The existing pavement surface, constructed in 1962, was extremely deteriorated due to tire chain abrasion. The pavement is subjected to large daily temperature fluctuations and severe freeze-thaw conditions. The existing pavement is non-reinforced PCC with skewed joints at 15 foot spacings. The pavement cross section consists of 1.00 ft subbase, 0.33 ft cement treated base and 0.67 ft portland cement concrete (Figure 2). Photographs showing the pavement condition before overlayment are presented in Figures 3 and 4.

The 1983 average daily traffic (ADT) (4) for this 4-lane freeway was 9750 with a truck ADT of 950. The average annual rainfall is 61 inches including an average annual snowfall of 410 inches (5).

Project Details

A prebid meeting was held in July 1981 to acquaint potential contractors and material suppliers with the project. This was considered necessary due to the new technology inherent in the project. The contract (03-217324) was awarded in September to low bidder Frank W. Pozar Construction Company of Fresno, California. It was considered too late in the year to begin construction so the project was suspended until the following spring.



LOCATION MAP

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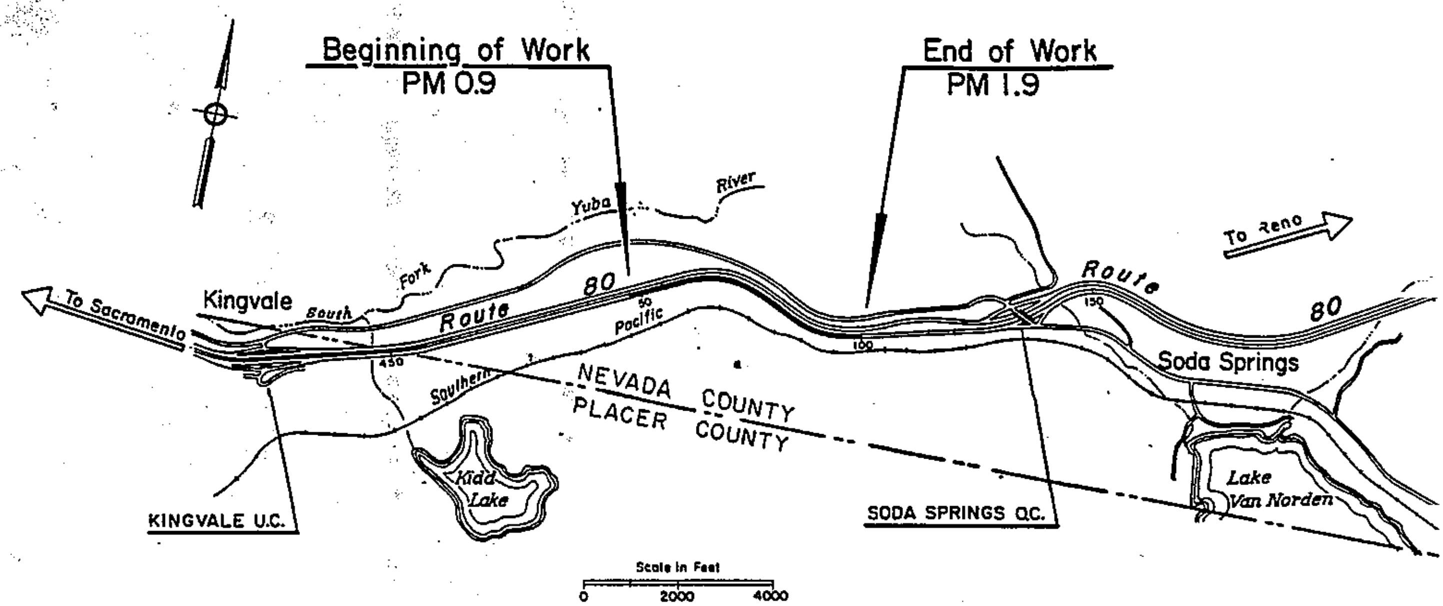
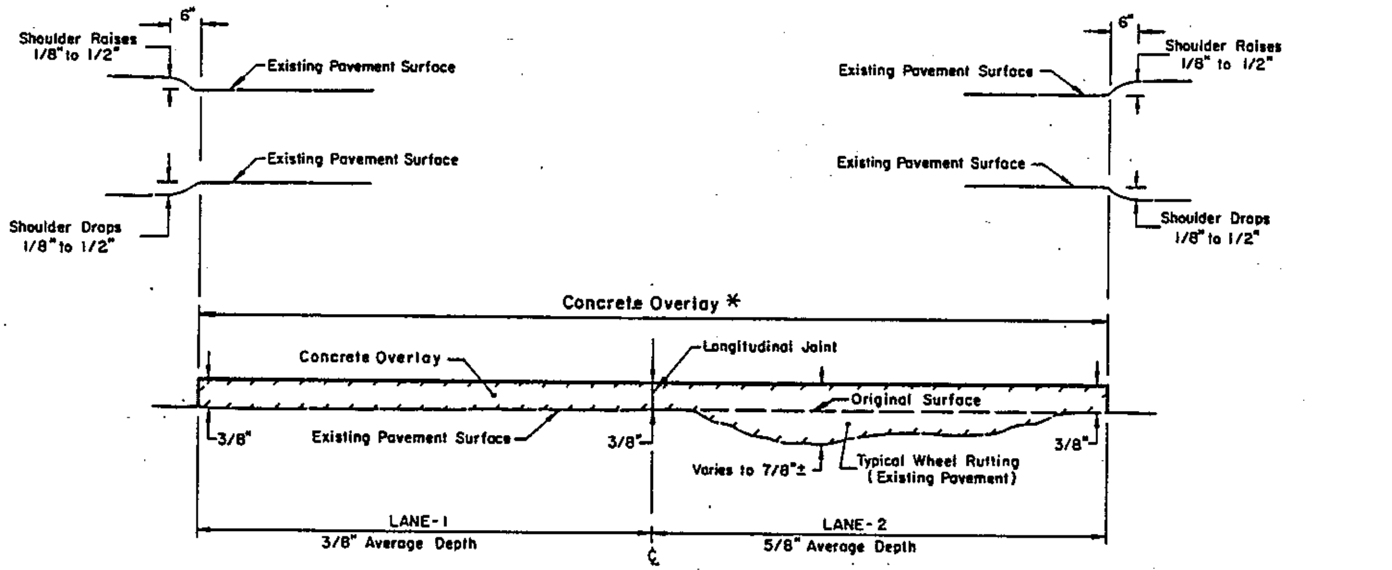


VICINITY MAP

Figure 1



Note:

Longitudinal contact joint to be directly over existing longitudinal joint.

TYPICAL OVERLAY SECTION

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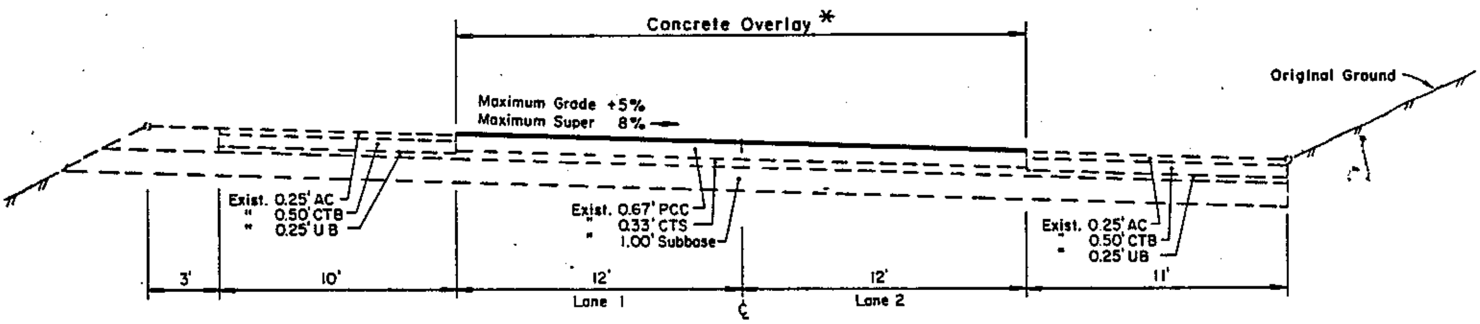


PM 0.9 to PM 1.9

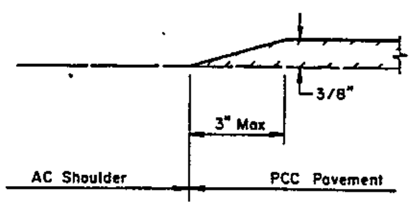
EASTBOUND LANES

TYPICAL CROSS SECTION

No Scale

Concrete Overlay *

– Magnesium Phosphate Concrete Overlay	P.M. 0.90 to P.M. 1.23
Methyl Methacrylate Polymer Concrete Overlay	P.M. 1.23 to P.M. 1.56
Polyester Styrene Polymer Concrete Overlay	P.M. 1.56 to P.M. 1.96



OPTIONAL EDGE TREATMENT

Figure 2

ABBREVIATIONS

AC............Asphalt Concrete
CTB..........Cement Treated Base
UB............Untreated Base
PCC...........Portland Cement Concrete
CTS...........Cement Treated Subbase
CMP..........Corrugated Metal Pipe
P.M...........Post Mile
Max..........Maximum

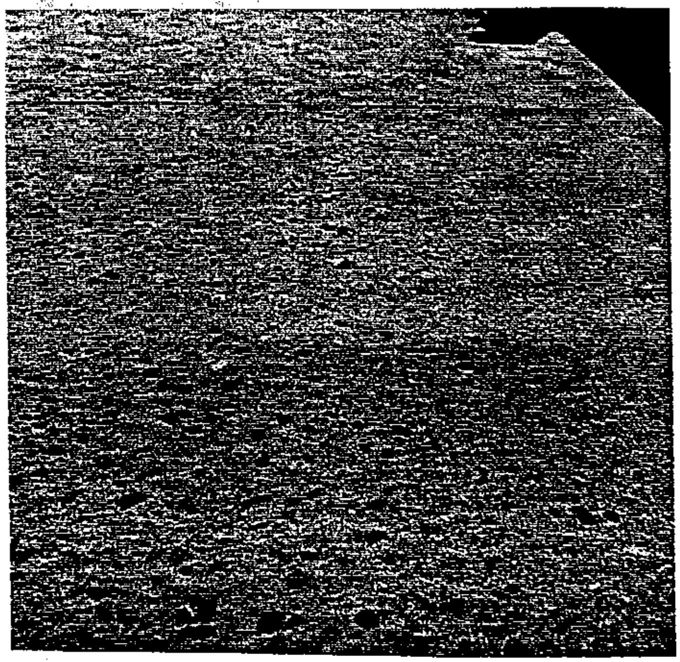


Figure 3 - Photograph showing PCC pavement condition prior to overlayment. Note the exposed coarse aggregate due to tire chain abrasion.

Figure 4 - Existing PCC surface after the prime coat for the MMA overlay has been applied.

The project called for a 3/8-inch minimum thickness overlay on the two eastbound lanes. Due to excessive wear and rutting of the outside lane, actual thicknesses of up to one inch were required to eliminate the irregular surface. Treatment of the inner and outer shoulders was not considered necessary. The one-mile section was divided equally among the three materials tested.

Crack Repair Strategies

A crack survey was made of each slab in order to monitor the various crack treatment strategies described below. Most existing pavement cracks were longitudinal and all cracking was located in the outer lane. Most of these cracks were from 1/8 inch to 3/8 inch wide at the surface.

Six different crack treatments were implemented by Contract Change Order in an attempt to prevent reflective cracking of the overlays.

1. Sawcut across the crack, remove concrete 2 inches wide, 4 inches deep and 24 inches long at 30-inch centers; center a #4 reinforcing bar in the resulting slot and fill with MMA concrete.

2. Same as No. 1 except saw a cut parallel to the crack at each end of the transverse cut and place a #4 "U" shaped reinforcing bar with a 7-inch bend on each end.

3. Sawcut and rout along the crack to a width of 1 inch and depth of 2 inches and fill with MMA concrete.

4. Same as No. 3 except remove 4-inch diameter full-depth cores along the crack at 30-inch intervals and fill with MMA concrete.

5. Fill cracks with high molecular weight methacrylate resin of low volatility and viscosity. This strategy was handled by Transportation Laboratory personnel. The resin was catalyzed in small quantities and injected into the cracks with plastic squeeze bottles. If the crack was not filled after the second injection, the resin for the third injection was either thickened by adding an acryloid or by adding dry sand.

6. Do nothing.

The surface preparation consisted of sandblasting and air sweeping. All materials were applied to a clean dry surface. The relatively few spalls in the existing concrete were patched with magnesium phosphate concrete prior to overlaying. Two 2-1/2 cubic foot capacity rotating drum mixers were used for mixing the overlay materials. The mixers were attached to the back of a truck so they could be charged from the truck bed. Concrete buggies were used to transport the concrete. A strike-off screed was placed on 3/8-inch steel screed rails set to grade. Grade control was established from the high point of the existing slabs. Existing transverse joints were referenced so that saw cutting the new joints would match the existing pavement joints. A caulking compound of either butyl rubber or acrylic latex was specified and placed in the existing joints to prevent intrusion by the overlay material. Although sawing of the longitudinal joint was not originally planned, the Engineer decided that it was needed and provided for it by Contract Change Order.

Methyl Methacrylate (MMA) Concrete

The contractor elected to begin with the MMA system. This section is along a curve where the superelevation is approximately 8%. Traffic was detoured to the inside lane (Lane 1) and the paving of Lane 2 began on August 11, 1982. Adhesive Engineering Company, suppliers of the MMA concrete materials, furnished technical assistance for the placement of the MMA overlay. The methyl methacrylate resin used for the concrete was Concresive 2020X. A prime coat of Concresive 2042 was applied by spray equipment and allowed to polymerize prior to placing the overlay concrete. The MMA concrete mix was a two-component, preproportioned system consisting of (A) resin and (B) dry bagged aggregate mixed at a 6.5% A to 93.5% B ratio by weight. The resin is highly volatile and flammable, so safety precautions had to be strictly observed. MMA concrete properties are listed in Table 1.

Problems were encountered with the strike-off and finishing procedures. Delays were caused due to the MMA resin sticking to the strike-off pan. Widening the pan so that fresh resin contacted the pan for a longer time period solved the sticking problem. Although the MMA concrete had been formulated to have low flow characteristics, there were problems maintaining material on the high side of the pavement slope. The removal of the vibrator from the screed helped the flow problem somewhat, but may have resulted in less consolidation of the overlay. The use of a long-handled float also helped crowd the material upgrade.

It was obvious that the texture and skid resistance, resulting from the strike-off and float operations, would not be satisfactory. Texturing with a long handled push broom solved this problem.

Initial progress was slow, but improved from 80 and 160 lineal feet per day on the first two days to 410 lineal feet on the third day. Paving was done in 12-foot lane widths. Setting time of the MMA concrete varied from 20 to 45 minutes depending on ambient and pavement temperatures. The transverse and longitudinal joints were sawed two to three hours after overlaying. The design thickness of 3/8 inch was exceeded at times due to difficulty in establishing precise grades and due to pavement rutting.

TABLE 1

Typical Results of Testing of Overlay Materials

By California Tentative Test Methods

Material	Compressive Strength(psi)		Flexural Strength (psi)	Abrasion Resistance (grams loss)	Bonding Strength to		"E" (psi)	Tensile Pull off of overlays** (psi) (9/8/82)
	3 Hr *	24 Hr	24 Hr	24 Hr	Dry PCC (psi)	SSD-PCC (psi)	24 Hr	
Magnesium Phosphate 'Set 45'	4000	6000	800	26	650	300	$4x10^6$	350
Methylmeth-acrylate "Concresive 2020"	7000	9000	2400	10	Failed PCC	Failed PCC	$2x10^6$	300
Polyester-Styrene "Reichhold Chemical"	3000	7000	1700	3	Failed PCC	Failed PCC	$1x10^6$	315

* Early Strength gain is dependent on catalyst level or initial set time.

** Two inch diameter direct pull off tests - average of two tests taken in lane No. 1

It was decided to shorten the length of the sections since the material cost overrun to finish the proposed 1760 foot sections would have been considerable. Paving was stopped in Lane 2 after 4 days and 1135 feet. Lane 1 was paved a distance of 1060 feet in 2 days before running out of material.

The sequence of events involved in paving this portion of the project is shown in Figures 5 through 8.

Polyester Concrete

The second section to be placed was the polyester-styrene concrete. The polyester-styrene concrete consisted of a mixture of Reichhold Chemical Company isophthalic polyester-styrene resin "Polylite 98-507" and dry bagged aggregate. TransLab specified the mix design and resin. The polyester-styrene concrete resin is a blend of polyester dissolved in styrene monomer. The resin was promoted with a metallic drier. Also, a minimum 0.5% silane coupler was added to improve the polyester resin bond to aggregate and to the PCC substrate. The silane coupler specified was an organosilane ester, gamma-methacryloxypropyltrimethoxysilane. The resin characteristics are listed in the special provisions included in the appendix. The resin was initiated with methylethylketone peroxide (MEKP). The resin gel time can be controlled to some extent by varying the initiator (MEKP) percentage. The batch design was 1/3 pea gravel, 2/3 sand, 11% polyester-styrene resin by weight of dry aggregate and 1% methylethylketone peroxide (MEKP), by weight of resin. The polyester-styrene resin was manufactured with the promoter (cobalt napthanate) and inhibitor added to the resin. A bond coat, using the same resin, was applied immediately prior to placement of the polyester-styrene concrete overlay.

Construction of Methylmethacrylate (MMA) Polymer Concrete Overlay.

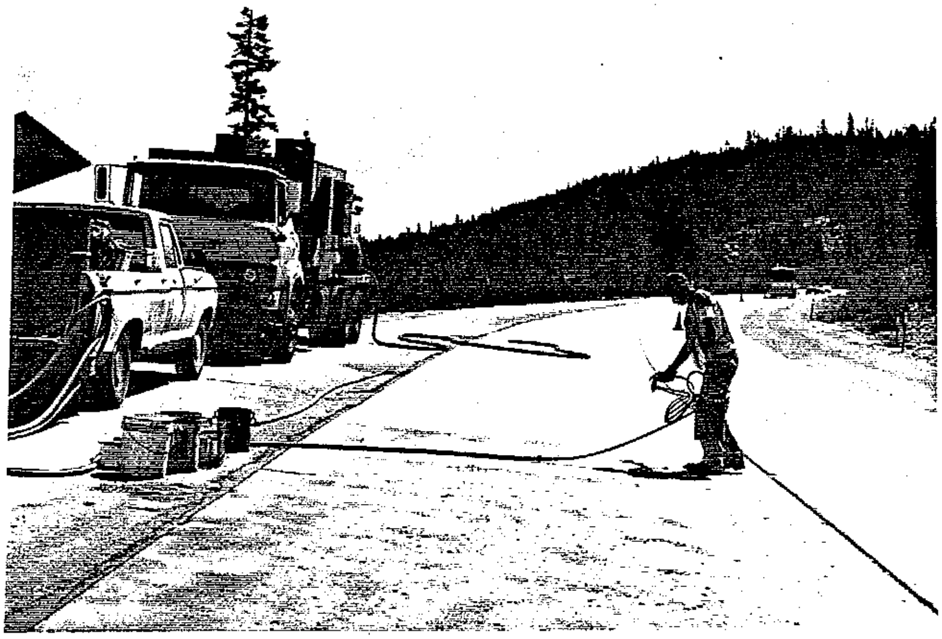


Figure 5 - Application of the MMA prime coat on the sandblasted surface. Note discoloration due to inadequate surface preparation.

Figure 6 - Setting the screed rails for MMA polymer concrete overlay.

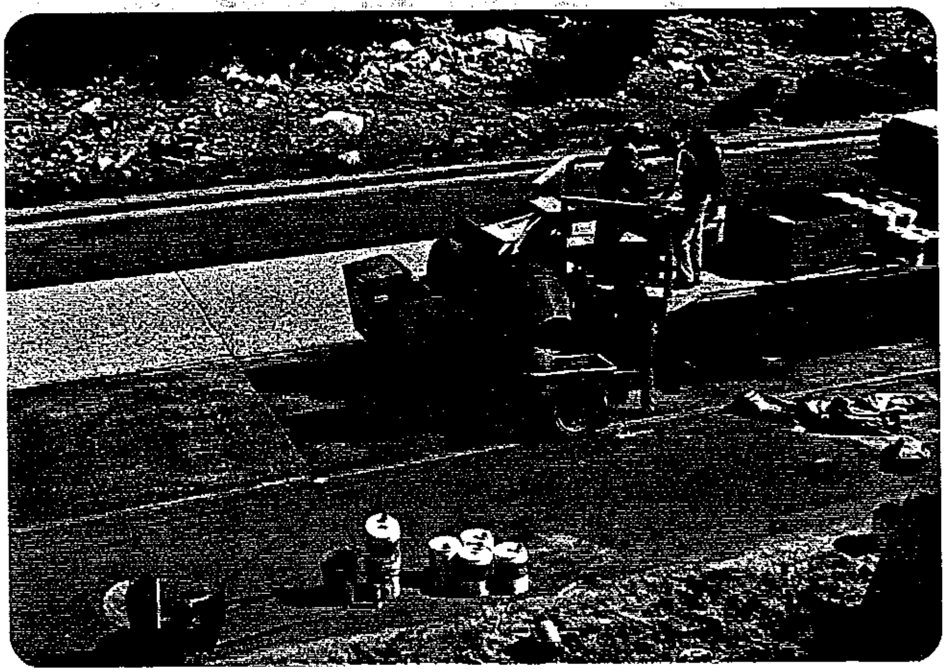


Figure 7 - Mixers used for MMA polymer concrete.

Figure 8 - Placing and finishing of MMA polymer concrete.

The aggregate grading is shown in the appendix. Well rounded, hard, low absorption aggregates are best suited for workability and performance of polyester-styrene concrete. Due to the viscosity of polyester-styrene resin, a special grading, low in fines, is required to allow for efficient mixing. The workability of the polyester-styrene concrete is directly related to the viscosity of the binder resin. A significant function of the styrene is to decrease the viscosity which improves the wetting properties of the resin. This permits reducing the resin content to a minimum value. Laboratory tests indicated that the optimum amount of styrene for workability was 45 to 50% of the finished resin and that additional styrene had detrimental effects. The maximum aggregate size was 3/8 inch pea gravel. The resin and aggregate were formulated with the highest aggregate loading and the lowest percent resin possible to obtain an efficient, workable mix. This reduced the cost but, more importantly, reduced the initial shrinkage and resulted in an overlay concrete which had a modulus of elasticity and coefficient of thermal expansion closer to that of the PCC substrate.

Technical assistance was provided by Reichhold Chemical Company. Typical polyester concrete properties are listed in Table 1.

The mixing and placing procedures were similar to those used for the MMA concrete. Some hand finishing was necessary to smooth out occasional surface irregularities. The polyester concrete proved to be cohesive and workable. The broom finish did not result in a coarse surface texture although it provided adequate skid resistance. A concrete edging tool worked well to seal the edge of the overlay and provided a longitudinal joint without the need for saw cutting. Vibration was not used on the screed since the vibrator had been removed for the MMA concrete. This resulted in a poorly compacted polyester-styrene concrete overlay. The setting time of the concrete varied from 30 minutes to 1 hour depending on temperature. A set time of not less than 45 minutes is recommended to prevent possible damage to the bond line due to early resin shrinkage. The transverse joints were sawed approximately two hours after concrete placement.

The paving sequence used for the polyester-styrene concrete overlay is shown in Figures 9 through 14. A distance of 1360 lineal feet was paved in Lane 2 over a three day period. Lane 1 was paved a distance of 1345 lineal feet in three days before running out of bagged aggregate.

Magnesium Phosphate Concrete

The final section placed was the magnesium phosphate concrete. This material was formulated by Dry Mix Products Company, Roseville, California, to meet Caltrans specifications for low flow characteristics and 25 minute set time. The extended set time was required to minimize the decarbonation of the substrate, a characteristic of magnesium phosphate. Magnesium phosphate concrete is produced by calcining mined magnesia to form magnesium and calcium oxides. The hardening reaction begins by adding phosphoric acid which yields magnesium phosphate and calcium phosphate. This is a chemical reaction and not a hydration reaction.

Magnesium phosphate will react with aluminum, so aluminum tools or mixing bowls should not be used. No additional water should be added simply to aid finishing. This results in a high water content at the surface which will result in high surface abrasion loss. Curing seals cannot be used as they will inhibit the hardening process, since the reaction gases must be allowed to escape.

The set time may be retarded by the addition of Borax or other buffers. Laboratory tests indicate that one ounce of Borax per 50 lb of mix will retard the set time five minutes at 72°F. If the material is formulated to set up too rapidly, a decarbonation reaction with the portland cement paste may occur and greatly reduce the bonding capacity. The carbon dioxide liberated in the decarbonation reaction causes bubbles to form on the bond line, thereby significantly decreasing the bonding area. Figure 15 is a photograph showing the bubbles resulting from the decarbonation reaction at the bond interface. The decarbonation reaction effect may be reduced by slowing the setting time of the concrete with the addition of retarders and by abrasively preparing the bonding surface to remove a percentage of the portland cement paste.

The single component magnesium phosphate concrete was extended 50% with pea gravel. The bond surface was sandblasted and air swept. The concrete was placed without a bond coat on the dry substrate. The concrete was workable and easy to finish. The magnesium phosphate concrete properties are listed in Table 1. To assure adequate skid resistance, dry aggregate was broadcast on the surface before the material hardened. The joints were sawed approximately two hours after the material hardened.

A continuous mix machine was used initially to place the concrete. It failed to provide the concrete fast enough, so the contractor reverted to the mixing technique used for the other materials. The paving sequence is shown in Figures 16 through 19.

Construction of Polyester Styrene Polymer Concrete Overlay.

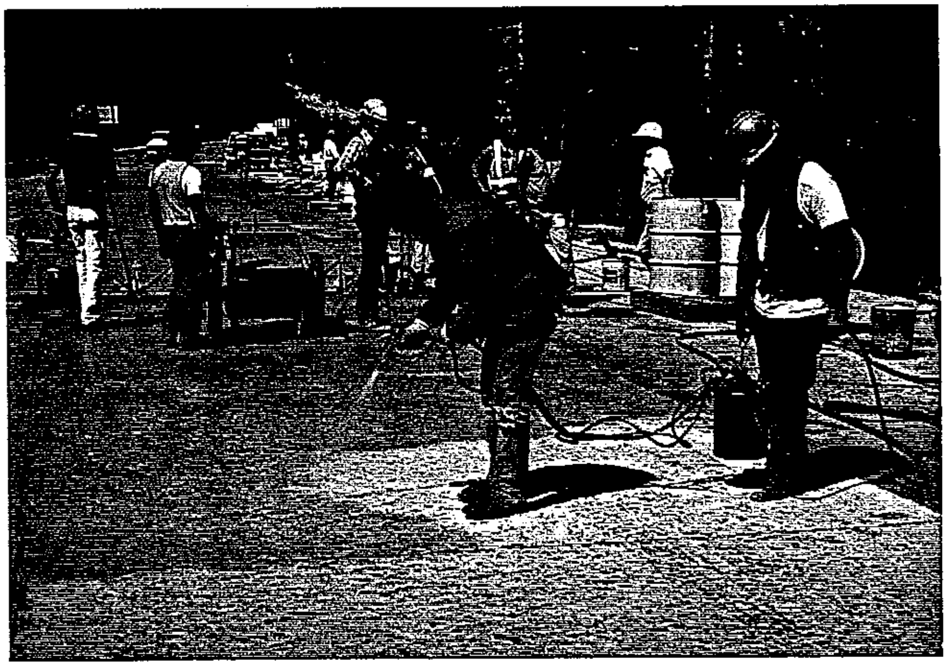


Figure 9 - Application of polyester resin prime coat on sand blasted PCC pavement.

Figure 10 - Polyester resin concrete was mixed in common PCC drum mixers.

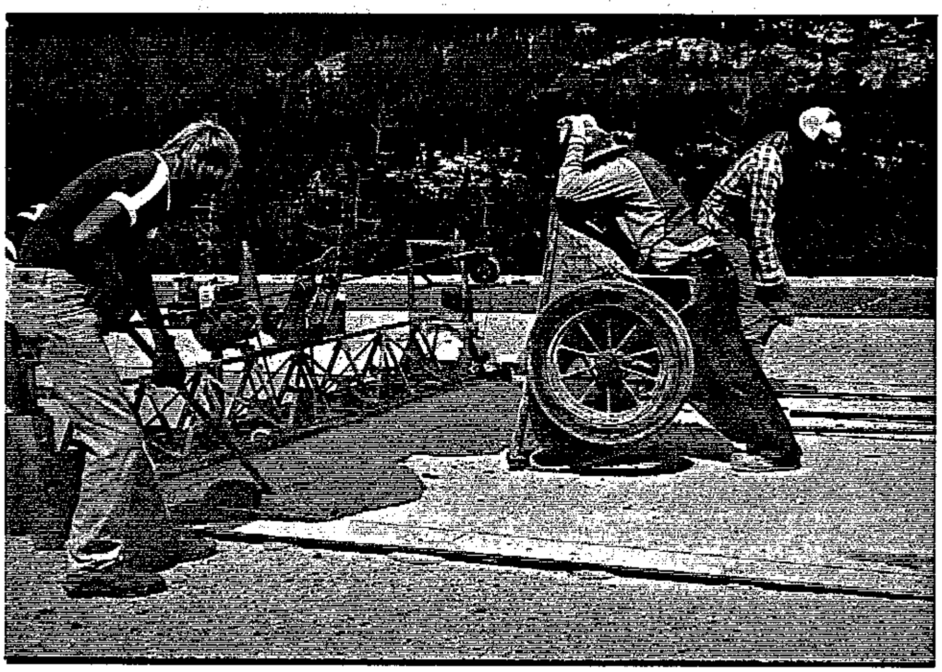


Figure 11 - Placing of 3/4" thick polyester concrete overlay.

Figure 12 - Finishing surface of polyester concrete overlay.

Figure 13 - Finishing longitudinal edges of polyester concrete overlay forming a longitudinal joint.

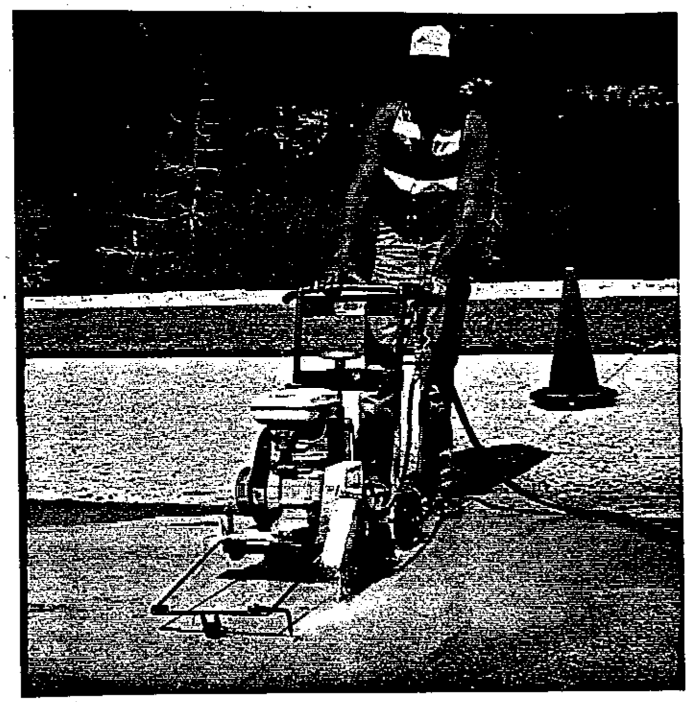


Figure 14 - Sawcutting transverse joints in polyester concrete overlay over existing PCC joints.

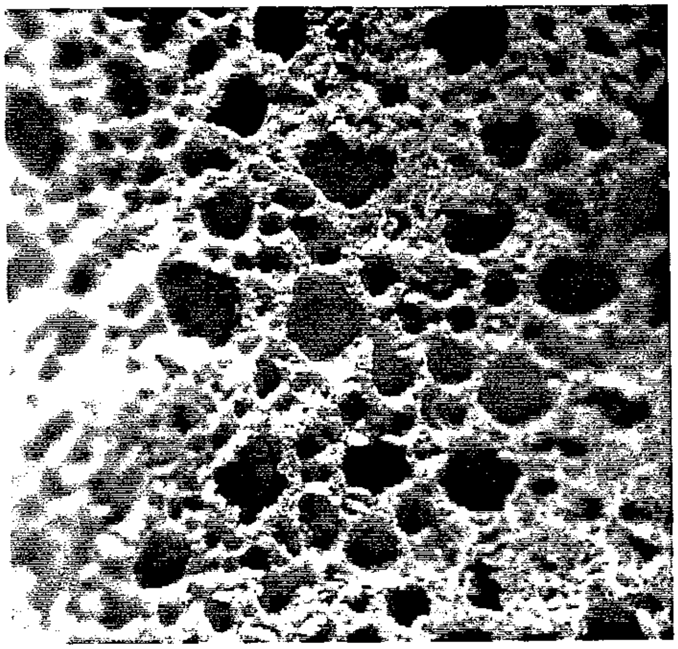


Figure 15 - Photo showing decarbonation reaction on bond line of single component magnesium phosphate patching material magnified 28X.

Construction of Magnesium Phosphate Concrete Overlay.

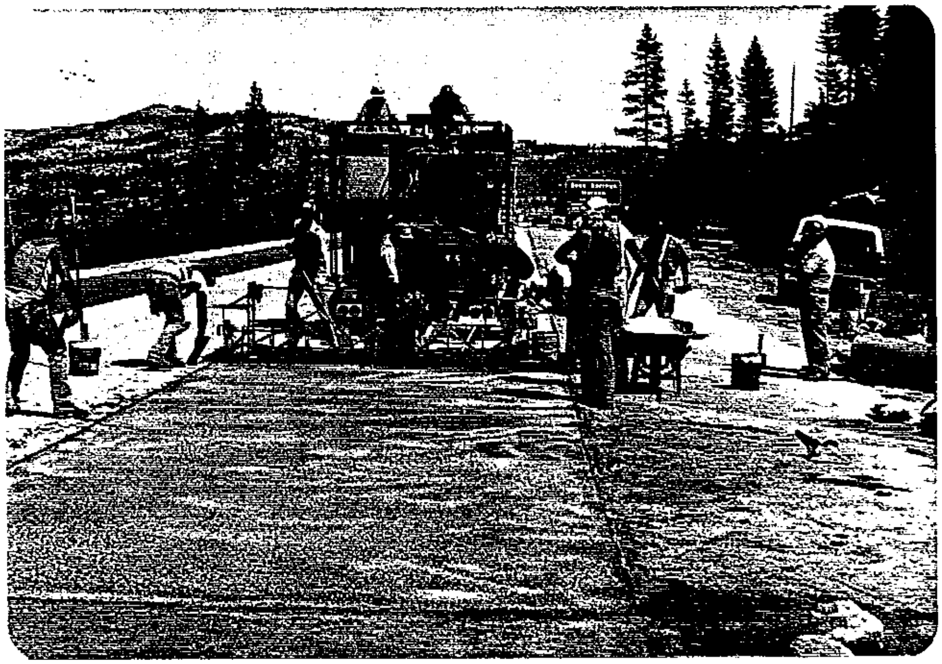


Figure 16 - Utilizing continuous auger mixer for magnesium phosphate concrete.

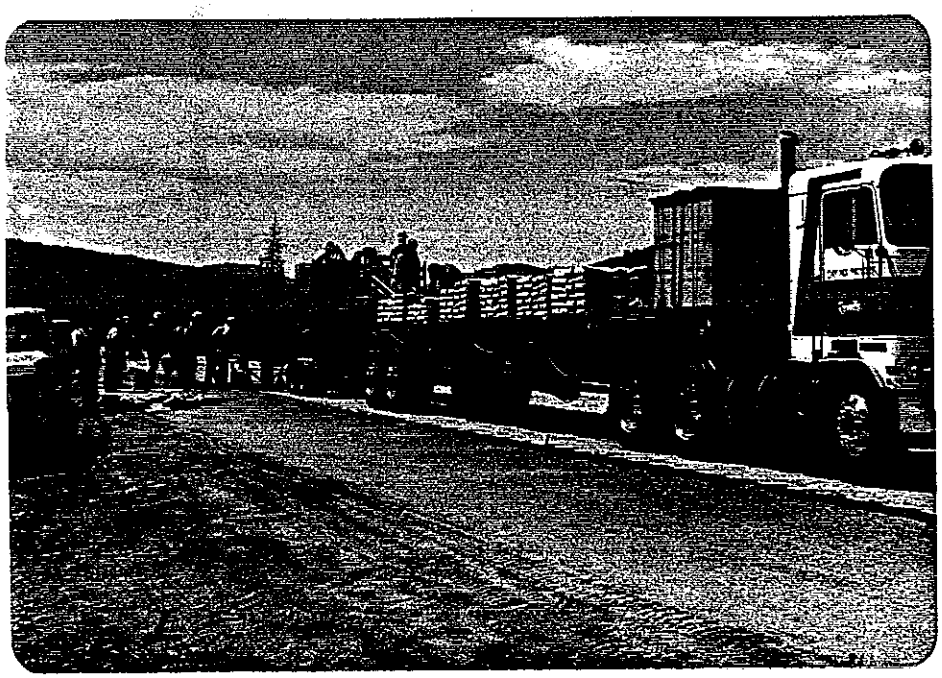


Figure 17 - Supply truck for continuous mixer placing magnesium phosphate concrete.

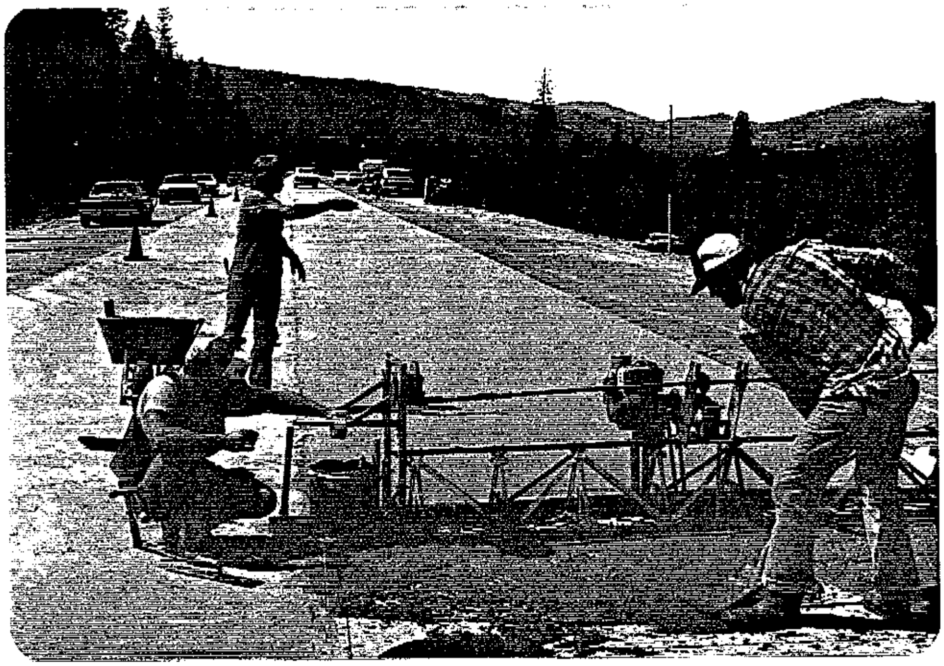


Figure 18 - Placing magnesium phosphate concrete overlay.

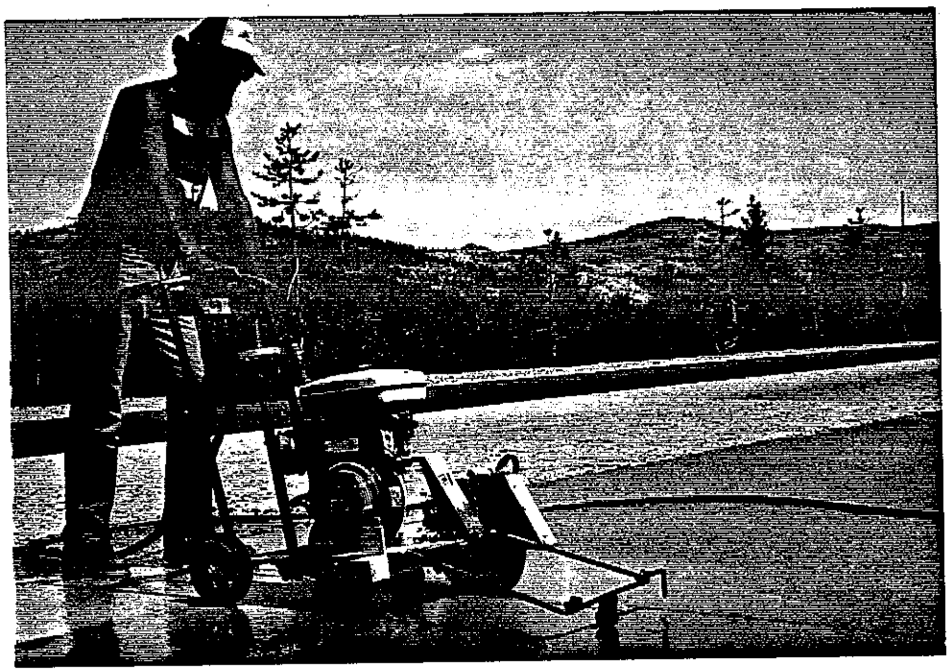


Figure 19 - Sawing transverse joints through magnesium phosphate concrete overlay.

COST DISCUSSION

The low bid (submitted by Frank W. Pozar) of $459,996 was 3.95% over the Engineers estimate of $442,505. The contract had five bids submitted and the bid summary is included in the appendix. The bid items are summarized in Table 2.

TABLE 2

Bid Item	Unit	Estimated Quantity	Low Bidder Estimate (Dollars)	Average of Five Bids (Dollars)
Traffic Control	LS	-	34,626	33,805
Saw Transverse Weakened Plane Joint	LF	8,800	1.10	1.14
Concrete Surface Preparation	SQ YD	14,500	1.75	2.15
Magnesium Phosphate Concrete Overlay	CF	1,930	61.00	71.20
Methyl Methacrylate Polymer Concrete Overlay	CF	1,930	96.00	111.20
Polyester-Styrene Polymer Concrete Overlay	CF	1,930	44.00	59.80

The polyester-styrene polymer concrete overlay was the most inexpensive material while the methyl methacrylate polymer concrete overlay was the most expensive at nearly twice the cost of the polyester-styrene overlay.

Magnesium Phosphate Concrete

All original pavement cracks have reflected through the overlay in spite of all crack repair strategies. Reflective cracks and numerous joints have widened due to wear. Loss of bond, cracking and spalling of the overlay have occurred along most cracks and joints. The durability of the bonded areas of the overlay appears to be satisfactory. The magnesium phosphate was not flexible enough to accommodate reflective cracking stresses. The surface preparation was not considered acceptable for the magnesium phosphate thin bonded overlay since all bond failures occurred at the bond interface. Overall, the magnesium phosphate concrete appears to be too brittle for use as a thin bonded overlay. Figures 20 through 23 show the condition of the magnesium phosphate concrete overlay. In October of 1984, the magnesium phosphate concrete overlay was removed by cold planing to restore ride quality. The removal cost was approximately $17,500.

Methyl Methacrylate Concrete

The methyl methacrylate concrete overlay has performed better than the magnesium phosphate concrete. Most of the original cracks have reflected through the overlay but remain tight. Some delamination and spalling has occurred along joints, cracks, and in the middle of several slabs. Fourteen panels have longitudinal cracks not previously mapped on the existing pavement. The overlay has worn through to the existing pavement in several sections but overall the overlay appears to have acceptable abrasion resistance. Figures 24 through 29 show the condition of the MMA overlay. Further evaluation is recommended if the bond strength to PCC can be improved.

Magnesium Phosphate Concrete Overlay.

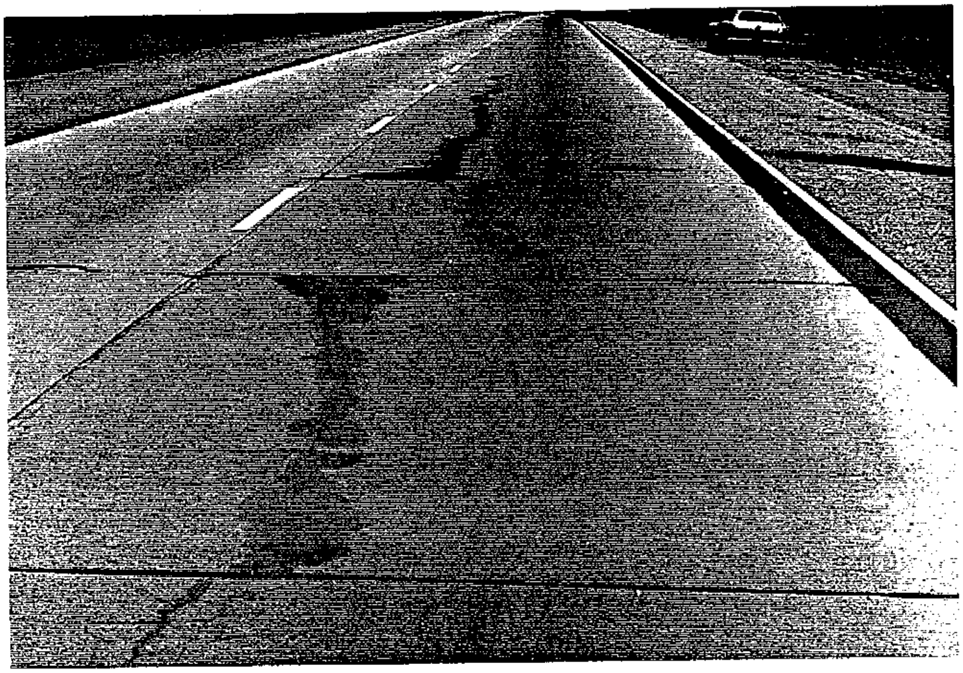


Figure 20 - Spring 1984 - Reflective cracks in magnesium phosphate concrete overlay after attempted repair by flooding with high molecular weight methacrylate resin.

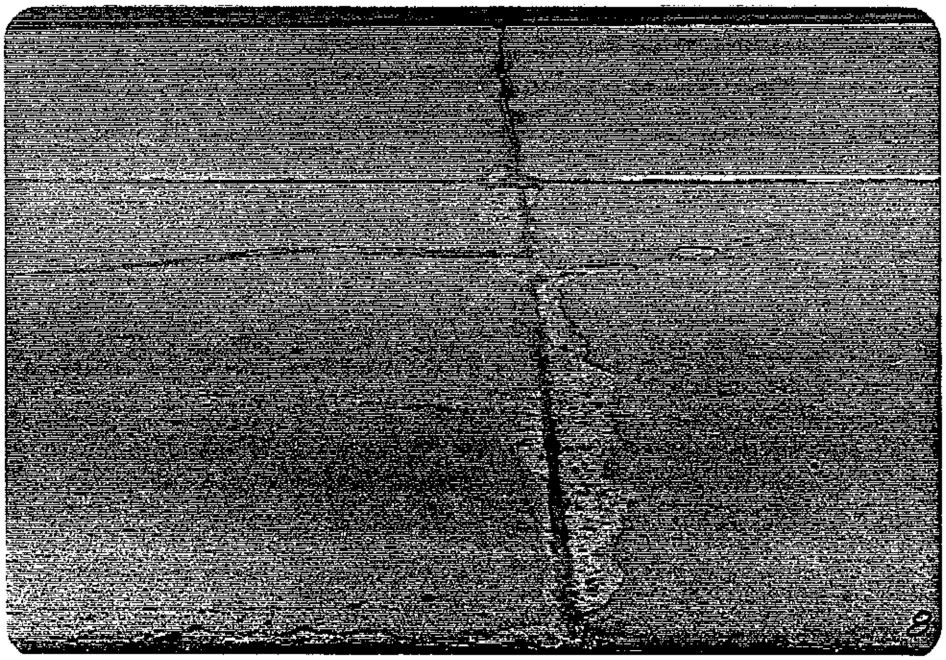


Figure 21 - Spring 1984 - Attrition and spalling near transverse joint of magnesium phosphate concrete overlay.

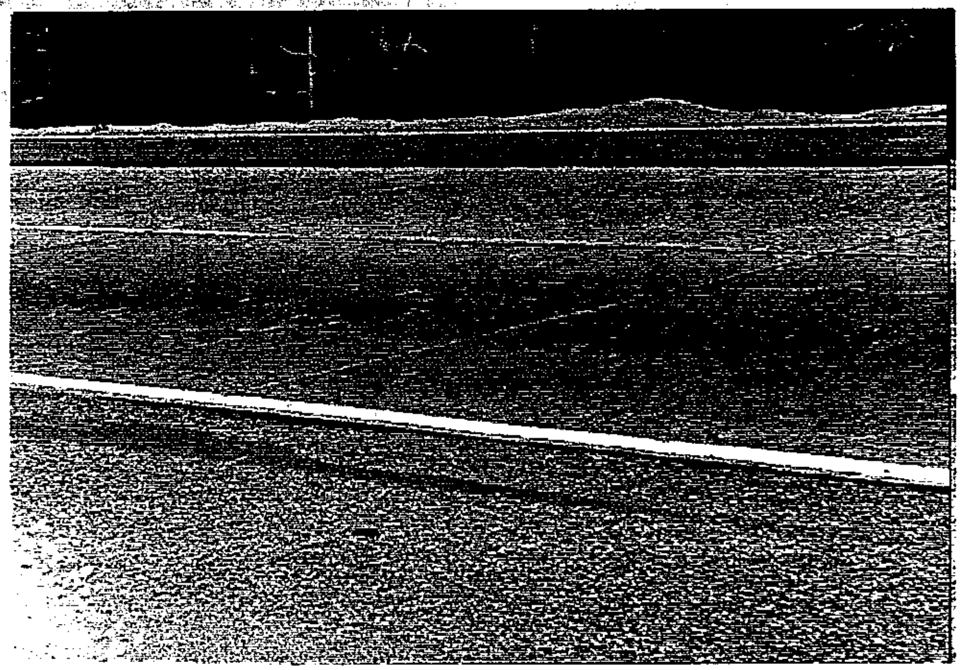


Figure 22 - Spring 1985 - Traces of magnesium phosphate concrete left after grinding off overlay.

Figure 23 - Spring 1985 - Exposed crack repair strategy after grinding off magnesium phosphate concrete overlay.

Methyl Methacrylate (MMA) Concrete Overlay.

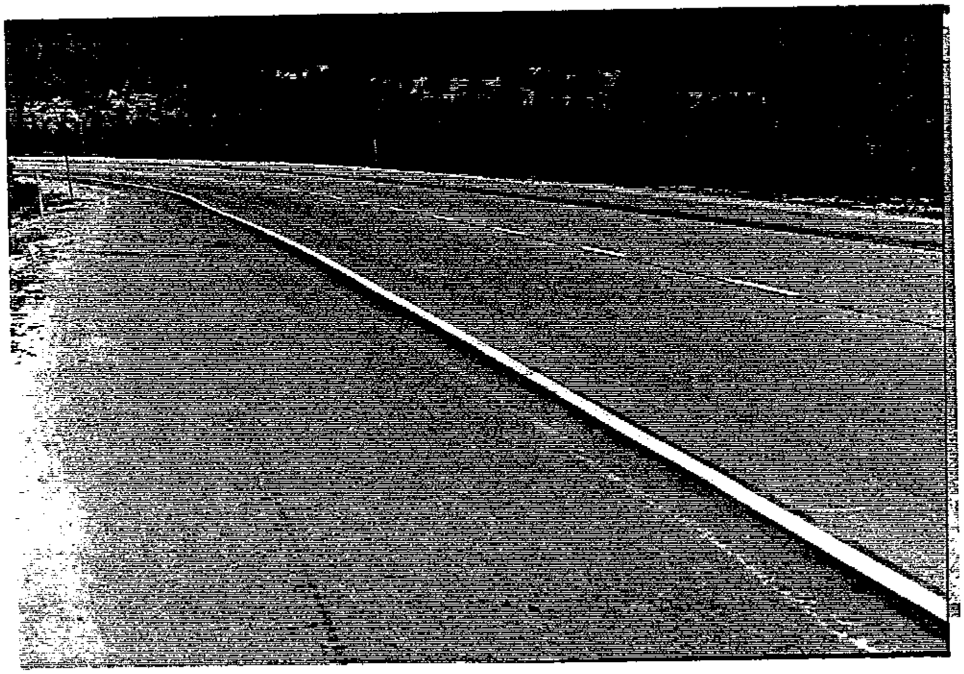


Figure 24 - Spring 1985, Overview of MMA Concrete Overlay.

Figure 25 - Spring 1985, Typical failure due to debonding and spalling of MMA Overlay.

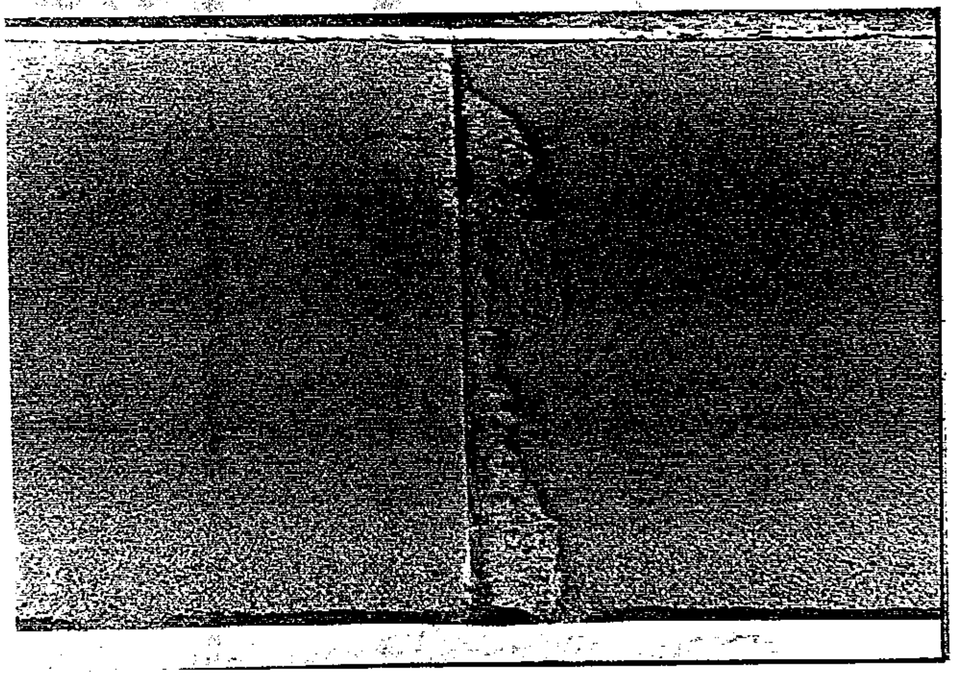


Figure 26 - Spring 1985 - Spalling of MMA concrete overlay near pavement joint.

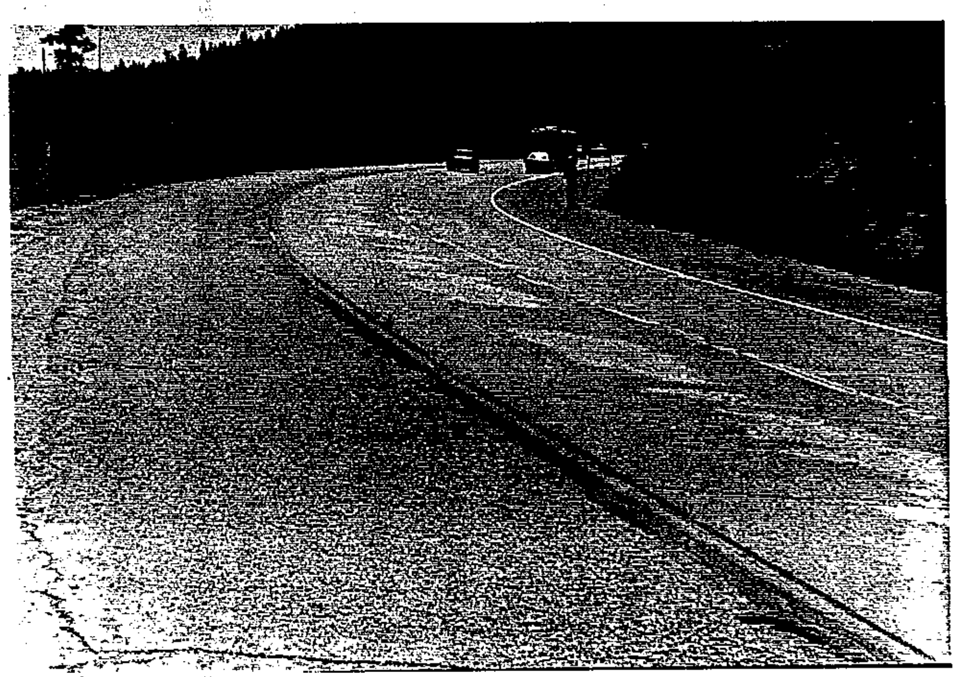


Figure 27 - Spring 1985 - MMA concrete overlay loss is more evident in the No. 1 lane.

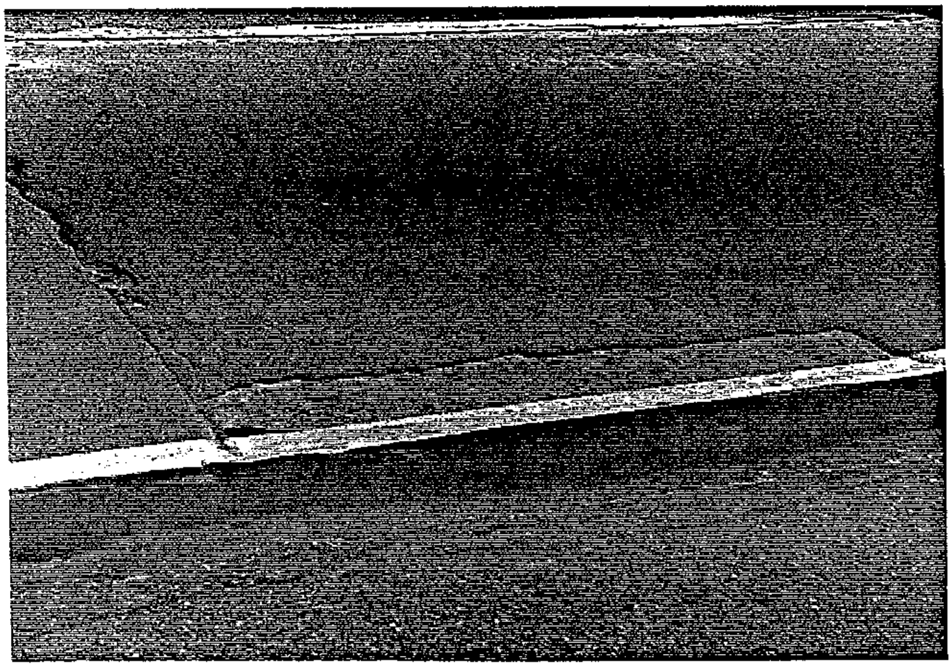


Figure 28 - Spring 1985 - Spalling of MMA concrete overlay adjacent to asphalt shoulder.

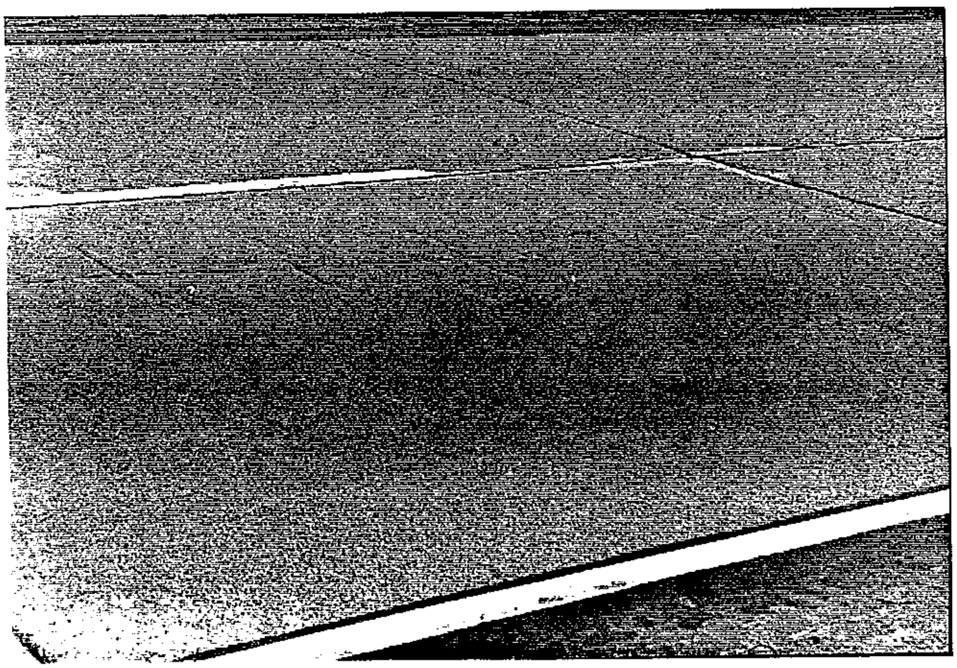


Figure 29 - Reflective cracking through MMA concrete overlay.

Polyester-Styrene Concrete

The polyester-styrene concrete is considered a limited success. The surface is irregular due to poor construction techniques. The outside edge of the No. 2 lane showed excessive wear due to the crowned shoulder and the abrasion from snowplow blades, but this is considered an extreme condition. The polyester-styrene concrete overlay prevented most reflective cracking even of the do nothing control cracks. There is no indication of any loss of bond. Some abrasion loss is apparent throughout the overlay. Overall, the polyester-styrene concrete is performing well. However, improved construction techniques are required. Figures 30 through 32 show the condition of the polyester-styrene overlay.

Crack Repair Strategies

All of the crack repair strategies were tried on each overlay. None of the crack repair treatments effectively prevented reflective cracking of the magnesium phosphate or methyl methacrylate overlays. The crack repair strategies did not perform any better than the do nothing controls on the polyester-styrene concrete overlay. It would, therefore, not appear to be beneficial to use these types of repair strategies on future overlay projects.

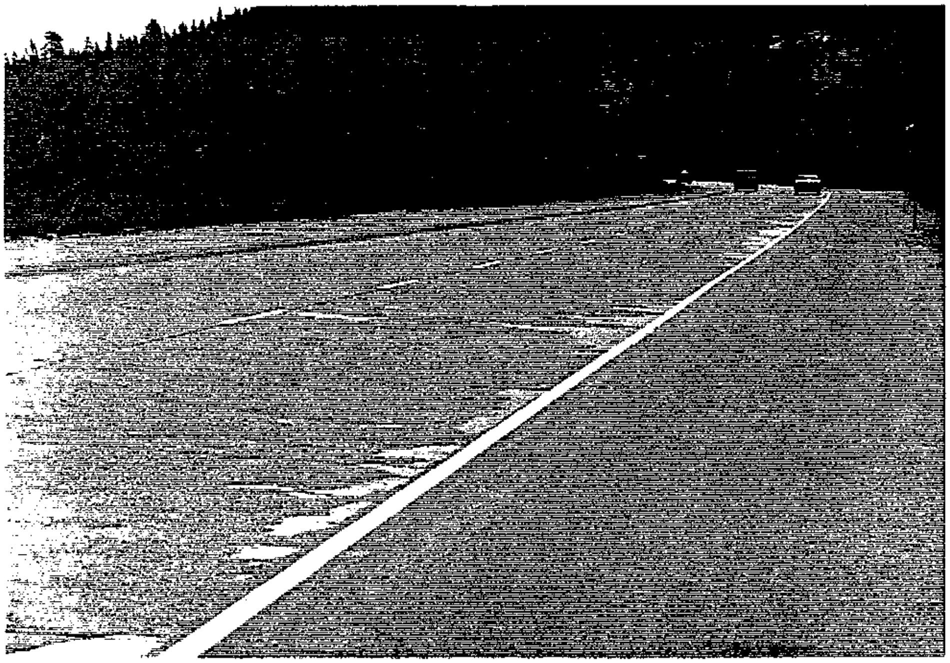


Figure 30 - Spring 1985 - Overview of polyester concrete overlay. Note excessive wear on crowned shoulder due to tire chain and snow plow abrasion.

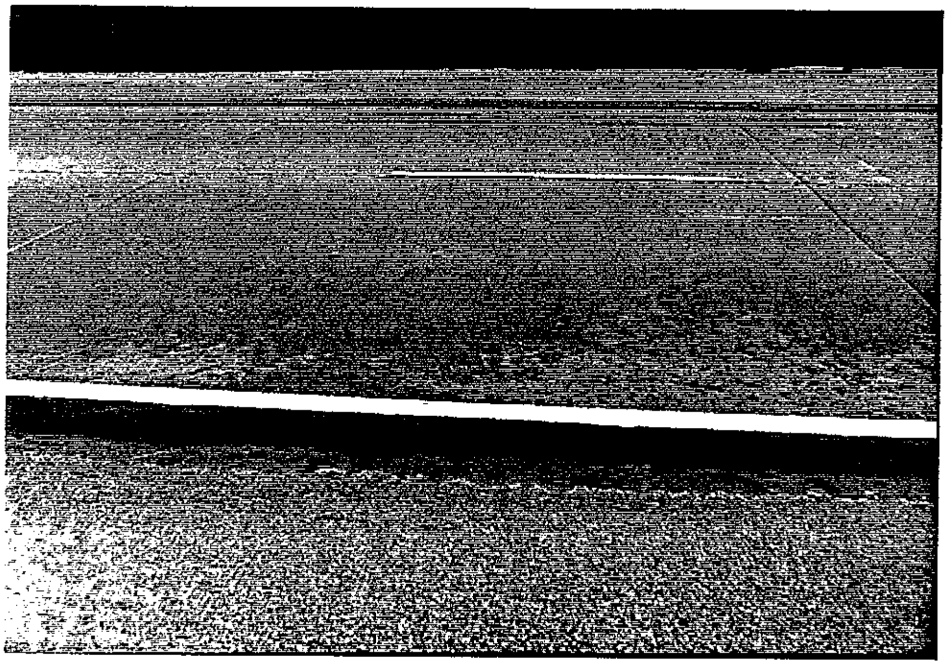


Figure 31 - Spring 1985 - Abrasion loss evident due to tire chain abrasion.

Figure 32 - Close up of abrasion loss of polyester-styrene concrete.

Skid Resistance

Skid resistance values (ASTM E-274) are tabulated below.

Material	SN_{40} (October 1982) Lane #1	Lane #2	SN_{40} (April 1984) Lane #1	Lane #2
Magnesium Phosphate	32	31	43	44
MMA	26	23	50	43
Polyester-Styrene	34	30	55	53
Control PCC	31	28	38	35

The MMA concrete had low initial skid resistance, but after the abrasion due to tire chains, all overlays exhibited better skid resistance than the adjacent PCC.

REFERENCES

1. Report No. FHWA-CA-TL-83104, California's Thin Bonded PCC Overlay, B. F. Neal, June 1983.

2. Report No. FHWA-CA-TL-83107, Experimental AC Overlays of PCC Pavement, Roger D. Smith, November 1983.

3. Report No. FHWA-CA-TL-85-16, "New Materials and Techniques for the Rehabilitation of Portland Cement Concrete", P. Krauss, October 1985.

4. 1983 Traffic Volumes on California State Highways, Caltrans, Office of Traffic.

5. Data collected at Caltrans Maintenance Yard, Kingvale, California.

APPENDIX

Excerpts from Special Provisions

and Bid Summary

STATE OF CALIFORNIA
BUSINESS, TRANSPORTATION AND HOUSING AGENCY
DEPARTMENT OF TRANSPORTATION

SPECIAL PROVISIONS

NOTICE TO CONTRACTORS
PROPOSAL AND
CONTRACT

FOR CONSTRUCTION ON

STATE HIGHWAY

IN

NEVADA COUNTY, FROM 1.5 MILES EAST OF
KINGVALE UNDERCROSSING TO 2.1 MILES WEST OF
SODA SPRINGS, DISTRICT 03, ROUTE 80.

For use in Connection with Standard Specifications
Dated January, 1981, Standard Plans Dated January, 1981,
General Prevailing Wage Rates Dated July, 1981,
and Labor Surcharge And Equipment Rental Rates.

CONTRACT NO. 03-217324

03-Nev-80-0.9/1.9

Federal Aid Project
IR-080-4(84)177

Bids Open: AUGUST 19, 1981

10-1.04 EXISTING HIGHWAY FACILITIES.--The work performed in connection with various existing highway facilities shall conform to the provisions in Section 15, "Existing Highway Facilities," of the Standard Specifications and these special provisions.

10-1.04A REPAIR OF CRACKS, SPALLS OR RAVELLING.--Volunteer cracks, spalls and ravelling, as selected by the Engineer, in the existing concrete pavement shall be repaired.

Repairing cracks, spalls of ravelling will be paid for as extra work as provided in Section 4-1.03D of the Standard Specifications.

10-1.05 CONCRETE SURFACE PREPARATION.--Concrete surface preparation shall consist of cleaning the surface of the existing portland cement concrete pavement which is to receive concrete pavement overlay. The entire area to receive concrete pavement overlay shall be cleaned by abrasive blast cleaning not more than 36 hours prior to placement of primer or concrete pavement overlay. All laitance and surface contaminants including, but not limited to rust, oil, paint, joint material, and other foreign material shall be removed from the surface of the existing portland cement concrete pavement.

Water may be used to aid in the abrasive blast cleaning, but the surface of the concrete must be dry for a minimum of 24 hours immediately prior to placing primer or concrete pavement overlay.

Equipment shall be fitted with suitable traps, filters, drip pans or other devices to prevent oil, fuel, grease or other deleterious matter from being deposited on the existing portland cement concrete pavement.

Any area that becomes contaminated shall be recleaned at the Contractor's expense.

Immediately prior to placing primer or concrete pavement overlay, the surface shall be further cleaned by compressed air blasting to remove loose dust and any loose material.

Concrete surface preparation will be measured by the square yard. The quantity of concrete surface preparation to be measured for payment will be determined by multiplying the width of the area prepared by the length prepared.

The contract price paid per square yard for concrete surface preparation shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals and for doing all the work involved in concrete surface preparation, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

10-1.06 METHYL METHACRYLATE POLYMER CONCRETE OVERLAY.--Methyl methacrylate polymer concrete overlay shall conform to the details shown on the plans and the requirements of these special provisions.

The Contractor's attention is directed to the section entitled "Order of Work" of these special provisions concerning polymer concrete and primer.

The polymer concrete shall be a two-component system consisting of a powder and a liquid. The powder may be extended with aggregate as recommended by the manufacturer. Powder and aggregate shall be packaged in a single container.

The two components shall be furnished as a complete system supplied by one of the following manufacturers, or equal:

Adhesive Engineering Company
1411 Industrial Road
San Carlos, California 94070
Phone (415) 592-7900

E. I. duPont deNemours Company
Chestnut Run
Wilmington, Delaware 19898
Phone (302) 999-4436

Transpo-Materials, Inc.
111 Cedar Street
New Rochelle, New Jersey 10801
Phone (914) 636-1000

The polymer concrete shall achieve a minimum compressive strength of 6,000 psi at 24 hours when tested by 2 inch cubes cast in standard brass molds. The molds and testing procedures shall conform to that specified in ASTM C109.

The polymer concrete shall achieve a minimum flexural bond strength of 400 psi and a minimum flexural strength of 1000 psi at 24 hours, as tested by the procedures specified in "Materials" of these special provisions.

Aggregate used to extend the powder component shall have 100 per cent passing the #4 screen and shall conform to the organic impurities and soundness requirements of ASTM C33. The moisture content of the aggregate shall not exceed 0.5 percent at the time of mixing when tested in accordance with California Test 226.

The Contractor shall furnish to the Engineer at least 15 days prior to placement a mix design and an amount of material sufficient to produce a minimum of 1 cubic foot of concrete. The Engineer will test the materials and determine the yield to be used for determining pay quantities. The yield will be determined as specified in "Materials" of these special provisions.

Prior to placing methyl methacrylate polymer concrete, a primer furnished by the same manufacturer that furnishes the concrete shall be applied to the existing surface after the surface is prepared as specified under "Concrete Surface Preparation" of these special provisions. The primer shall be a resin with a curing time of 15 to 60 minutes. The primer shall be applied to cover the entire surface area and shall be applied evenly so as to eliminate dry areas or ponding. Primer shall be covered with concrete within the period of time recommended by the manufacturer. Full compensation for furnishing and placing primer shall be considered as included in the contract price paid per cubic foot for methyl methacrylate polymer concrete overlay, and no additional compensation will be allowed therefor.

The concrete shall be formulated to provide curing within 45 minutes to two hours.

The concrete shall be mixed and placed according to the manufacturer's recommendations.

The surface temperature of the existing pavement shall be 40° F. or above, when primer is placed, and shall be dry for a minimum period of 24 hours prior to placing the primer.

The overlay for lanes 1 and 2 shall be placed in separate operations. The finished surface shall be smooth without irregularities, and the coefficient of friction shall be not less than 0.30 as determined by California Test 342.

The completed surface will be tested with a 12 foot straightedge at locations to be determined by the Engineer. When the straightedge is laid on finished pavement in a direction parallel with centerline or normal to centerline, the surface shall not vary more than 0.02 foot from the lower edge. Any high points in excess of these tolerances shall be removed by grinding.

No traffic or Contractor's equipment, other than joint sawing equipment, will be allowed on the overlay before a period of four hours has elapsed after the final finish, unless otherwide permitted by the Engineer.

Methyl methacrylate polymer concrete overlay will be measured by the cubic foot at the mixer. The volume to be paid for will be determined by the Engineer from calculations based on sack count and the yield from the mix design required elsewhere in these special provisions. The Contractor shall furnish suitable measuring devices to assure adequate proportioning of the materials and accurate measurement for pay quantities. The pay quantity will be the quantity actually used in the work, exclusive of wasted and unused material or material placed in excess of the dimensions shown on the plans.

The contract price paid per cubic foot for methyl methacrylate polymer concrete overlay shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals involved in constructing the overlay (including primer and any necessary grinding) as shown on the plans, and as provided in the Standard Specifications and these special provisions, and as directed by the Engineer.

10-1.07 POLYESTER STYRENE POLYMER CONCRETE OVERLAY.--Polyester styrene polymer concrete overlay shall conform to the details shown on the plans and the requirements of these special provisions.

The Contractor's attention is directed to the section entitled "Order of Work" of these special provisions concerning polymer concrete and primer.

Concrete shall be a polyester resin and graded concrete aggregate. The resin shall be an unsaturated isophthalic polyester styrene copolymer meeting the following requirements:

Viscosity	75 to 200 cps (77° F., 20 RPM)
Styrene Content	50% maximum
Specific Gravity	1.05 to 1.10 at 77° F.
Stability	6 months (dark at 77° F.)
Elongation	40% to 60%
Tensile Strength	2,500 psi minimum

The resin shall contain 0.5% silane bonding agent solution (based on the weight of polyester styrene resin) and a promoter compatible with a suitable methyl ethyl ketone peroxide initiator to provide a 15 to 20-minute gel time at 77° F. The silane shall be Union Carbide A174, Dow Corning Z6030, or equal.

The polyester resin shall be wax-free.

Aggregate for polyester styrene polymer concrete shall consist of 65 % fine aggregate and 35% coarse aggregate. The aggregates shall conform to the quality requirements of Section 90-2.02, "Aggregates," of the Standard Specifications and shall be within the following grading limits:

Fine Aggregate

Sieve Size	% Passing
3/8"	100
No. 4	95-100
No. 8	65-95
No. 16	45-80
No. 30	25-55
No. 50	10-35
No. 100	2-10
No. 200	0-5

Coarse Aggregate

Sieve Size	% Passing
3/8"	100
No. 4	0-30
No. 8	0-5
No. 16	0

Combined Aggregate

Sieve Size	% Passing
3/8"	100
No. 4	62-75
No. 8	42-64
No. 100	1-7
No. 200	0-3

Aggregate retained on the No. 4 and No. 8 sieves, when combined, shall have a maximum of 25% crushed particles when tested in accordance with California Test 205.

The moisture content of the aggregates shall not exceed 0.5% at the time of mixing with the resin when tested in accordance with California Test 226.

Resin shall be added to the aggregates at a rate of approximately 12% by weight of the dry aggregate. The Contractor shall furnish to the Engineer at least 15 days prior to placement an amount of material sufficient to produce a minimum of 1 cubic foot of concrete. The Engineer will test the materials and determine the yield to be used for determining pay quantities. The yield will be determined as specified in "Materials" of these special provisions.

Prior to placing polyester styrene polymer concrete, a prime coat shall be applied to the existing surface as prepared under "Concrete Surface Preparation" of these special provisions.

The prime coat shall consist of the same polyester resin used in the concrete. The prime coat shall be uniformly applied immediately ahead of the polyester concrete in a manner to completely cover the existing surface with no dry areas or ponding. The rate of spread shall be 1 gallon per 30 to 35 square yards of surface. If the prime coat resin becomes contaminated before concrete placement, the resin shall receive an addition blast cleaning and an additional prime coat of fresh resin shall be applied.

Full compensation for furnishing and placing primer shall be considered as included in the contract price paid per cubic foot for polyester styrene polymer concrete overlay, and no additional compensation will be allowed therefor.

The concrete shall be mixed and placed according to the resin manufacturer's recommendations.

The surface temperature of the existing pavement shall be 40° F. or above when primer is placed, and shall be dry for a minimum period of 24 hours prior to placing the primer.

The overlay for lanes 1 and 2 shall be placed in separate operations. The finished surface shall be smooth without irregularities.

The surface will be tested with a straightedge 12 feet long at locations to be determined by the Engineer. When the straightedge is laid on finished pavement in a direction parallel with centerline or normal to centerline, the surface shall not vary more than 0.02 foot from the lower edge. Any high points in excess of these tolerances shall be removed by grinding.

No traffic or Contractor's equipment, other than joint sawing equipment, will be allowed on the overlay before a period of four hours has elapsed after the final finish, unless otherwise permitted by the Engineer.

Polyester styrene polymer concrete overlay will be measured by the cubic foot at the mixer. The volume to be paid for will be determined by the Engineer from calculations based on the amount of resin used and the yield. The Contractor shall furnish suitable measuring devices to assure adequate proportioning of the materials and accurate measurement for pay quantities. The pay quantity will be the quantity actually used in the work, exclusive of wasted and unused material or material placed in excess of the dimensions shown on the plans.

The contract price paid per cubic foot for polyester styrene polymer concrete overlay shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals involved in constructing the overlay (including primer and any necessary grinding) as shown on the plans, and as provided in the Standard Specifications and these special provisions, and as directed by the Engineer.

10-1.08 MAGNESIUM PHOSPHATE CONCRETE OVERLAY.--Magnesium phosphate concrete overlay shall conform to the details shown on the plans, and the requirements of these special provisions.

Concrete shall be a single-component, water activated, rapid set, high strength, magnesium phosphate concrete available from Dry Mix Products Company, or equal. The concrete shall not be extended with additional aggregate.

Arrangements have been made to insure that any successful bidder can obtain magnesium phosphate concrete from the following source:

Dry Mix Products Company
Post Office Box 730
Roseville, California 95678
Phone (916) 783-8168

The price per cubic yard for magnesium phosphate concrete shall be $806.63. This does not include sales tax and is F.O.B. Roseville, California.

The above price will be firm for all orders placed on or before December 31, 1981.

The concrete shall be formulated for a nominal set time of 25 minutes at 70° F. and prior to use shall be stored in a cool, dry environment.

The concrete shall achieve a minimum flexural bond strength of 400 psi and a minimum flexural strength of 500 psi at 24 hours when tested by the procedures specified in "Materials" of these special provisions.

The concrete mix shall achieve a minimum compressive strength of 5,000 psi at 24 hours when tested by 2 inch cubes cast in standard brass molds. The molds and testing procedures shall conform to that specified in ASTM C109.

The Contractor shall furnish to the Engineer at least 15 days prior to placement an amount of material sufficient to produce a minimum of 1 cubic foot of concrete. The Engineer will test the material and determine the yield to be used for determining pay quantities. The yield will be determined as specified in "Materials" of these special provisions.

Mix water shall be free from oil and impurities and shall not contain more than 2,000 parts per million of chlorides as Cl nor more than 1,500 parts per million of sulfates as SO_4.

The ratio of concrete and water shall be between 6 and 7 volumes of concrete to 1 volume of water as directed by the Engineer.

Attention is directed to "Concrete Surface Preparation" of these special provisions. A primer will not be required for magnesium phosphate concrete overlay.

The surface temperature of the existing pavement shall be 40° F. or above and shall be dry, as determined by the Engineer, when the magnesium phosphate concrete is placed.

When the ambient temperature is 80° F. or above, and when required, the concrete and mix water shall be cooled to prolong the time of the concrete workability.

The concrete shall be mixed and placed according to the manufacturer's recommendations.

The overlay for lanes 1 and 2 shall be placed in separate operations. The finished surface shall be smooth without irregularities, and the coefficient of friction shall be not less than 0.30 as determined by California Test 342.

The surface will be tested with a straightedge 12 feet long at locations to be determined by the Engineer. When the straightedge is laid on finished pavement in a direction parallel with centerline or normal to centerline, the surface shall not vary more than 0.02 foot from the lower edge. Any high points in excess of these tolerances shall be removed by grinding.

No traffic or Contractor's equipment, other than joint sawing equipment, will be allowed on the overlay before a period of 4 hours has elapsed after the final finish, unless otherwise permitted by the Engineer.

Magnesium phosphate concrete overlay will be measured by the cubic foot at the mixer. The volume to be paid for will be determined by the Engineer from calculations based on sack count and the yield. The Contractor shall furnish suitable measuring devices to assure adequate proportioning of the materials and accurate measurement for pay quantities. The pay quantity will be the quantity actually used in the work, exclusive of wasted and unused material or material placed in excess of the dimensions shown on the plans.

The contract price paid per cubic foot for magnesium phosphate concrete overlay shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals involved in constructing the overlay (including any necessary grinding) as shown on the plans and as provided in the Standard Specifications and these special provisions, and as directed by the Engineer.

10-1.09 SAW TRANSVERSE WEAKENED PLANE JOINT.--Sawing transverse weakened plane joints shall conform to the requirements of Section 40-1.08B(1), "Sawing Method," of the Standard Specifications and these special provisions.

Transverse weakened plane joints shall be sawn completely through the new concrete overlay directly over all existing transverse joints. Existing joints shall be well marked by the Contractor prior to placing new concrete overlay to assure proper placement of sawn joints.

All transverse weakened plane joints shall be sawn within 3 hours after the concrete pavement overlay has been placed. The exact time will be determined by the Engineer.

Curing of sawed joints will not be required.

Saw transverse weakened plane joints will be measured by the linear foot along the joint actually sawed.

The contract price paid per linear foot for saw transverse weakened plane joint shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals and for doing all the work involved in sawing transverse weakened plane joints, complete in place, including marking the position of the existing joints prior to sawing, as shown on the plans, as specified in the Standard Specifications and these special provisions and as directed by the Engineer.

STATE OF CALIFORNIA — SACRAMENTO OPENINGS — BID SUMMARY — DEPARTMENT OF TRANSPORTATION

BID138
PAGE 1
08/20/81

BID OPENING DATE 08/19/81
CONTRACT NUMBER 03-217324
LOCATION 03-NEV-80-0.9/1.9

FROM 1.5 MI E OF KINGVALE UC TO 2.1 MI W OF SODA SPRINGS

CONCRETE OVERLAY

FEDERAL AID IR-080-4(84)177

PROPOSALS ISSUED 13 FUND TOTAL HA22 500,000 NUMBER OF WORKING DAYS 40
NUMBER OF BIDDERS 5 ENGINEERS EST 442,505.00 AMOUNT OVER 17,491.00 PERCENT OVER EST 3.95

BID RANK	BID TOTAL	BIDDER INFORMATION (NAME/ADDRESS/LOCATION)	
1	459,996.00	FRANK W. POZAR 4734 E CARMEN FRESNO CA 93703	209 251-4205
2	545,000.00	COFFMAN CONSTRUCTION, INC. 9601 AERO DRIVE SUITE 290 SAN DIEGO CA 92123	714 560-8131
3	549,430.00	HAUSCHILD CONSTRUCTION, INC. 21861 SHASTA LAKE ROAD EL TORO CA 92630	714 768-0955
4	593,800.00	WESLEY A. THOMAS CO., INC. 175 INDUSTRIAL WAY BENICIA CA 94510	707 745-9110
5	599,310.00	TEICHERT CONSTRUCTION PO BOX 15002 SACRAMENTO CA 95813	916 484-3311

03-217324
03-NEV-80
08/19/81

CONTRACT PROPOSAL OF LOW BIDDER

BID138
PAGE 2
08/20/81

ITEM NO.	ITEM CODE	ITEM DESCRIPTION	UNIT OF MEASURE	ESTIMATED QUANTITY	BID	AMOUNT
1	120100	TRAFFIC CONTROL SYSTEM	LS	LUMP SUM	34,626.00	34,626.00
2	402301	SAW TRANSVERSE WEAKENED PLANE JOINT	LF	8,800	1.10	9,680.00
3	017176	CONCRETE SURFACE PREPARATION	SQYD	14,500	1.75	25,375.00
4	017177	MAGNESIUM PHOSPHATE CONCRETE OVERLAY	CF	1,930	61.00	117,730.00
5	017178	METHYL METHACRYLATE POLYMER CONCRETE OVERLAY	CF	1,930	96.00	185,280.00
6	017179	POLYESTER STYRENE POLYMER CONCRETE OVERLAY	CF	1,930	44.00	84,920.00
7	840655	PAINT TRAFFIC STRIPE (1-COAT)	LF	10,600	0.15	1,590.00
8	840656	PAINT TRAFFIC STRIPE (2-COAT)	LF	5,300	0.15	795.00
					TOTAL	459,996.00

SUMMARY OF REMAINING BIDDERS

ITEM	SECOND BID	SECOND AMOUNT	THIRD BID	THIRD AMOUNT	FOURTH BID	FOURTH AMOUNT	FIFTH BID	FIFTH AMOUNT
1	33,400.00	33,400.00	30,000.00	30,000.00	15,000.00	15,000.00	56,000.00	56,000.00
2	1.00	8,800.00	0.60	5,280.00	2.00	17,600.00	1.00	8,800.00
3	2.00	29,000.00	2.00	29,000.00	3.00	43,500.00	2.00	29,000.00
4	70.00	135,100.00	70.00	135,100.00	80.00	154,400.00	75.00	144,750.00
5	110.00	212,300.00	110.00	212,300.00	120.00	231,600.00	120.00	231,600.00
6	60.00	115,800.00	70.00	135,100.00	60.00	115,800.00	65.00	125,450.00
7	0.50	5,300.00	0.15	1,590.00	1.00	10,600.00	0.20	2,120.00
8	1.00	5,300.00	0.20	1,060.00	1.00	5,300.00	0.30	1,590.00
TOTAL		545,000.00		549,430.00		593,800.00		599,310.00